Evaluation of Green House Gas Benefits for Renewable Energy Technologies

Introduction

The Renewable Portfolio Standard (RPS), established by Senate Bills 1078 (2002) and 107 (2006), currently requires utilities to provide renewable energy for 20 percent of the electricity sold by the utility by the end of 2010. The Public Utilities Commission (PUC) and the California Energy Commission (CEC) have adopted regulations and guidelines, respectively, to implement the RPS. The Governor subsequently issued an executive order that requires the Air Resources Board (ARB) to adopt a regulation, the renewable electricity standard (RES), requiring a 33 percent renewable energy be delivered by utilities in 2020. Additionally, the 33 percent RES would be consistent with the Climate Change Scoping Plan, approved by the ARB in December 2008, that recommends the adoption of a more aggressive RPS of 33 percent which would result in significant reductions in greenhouse gas (GHG) emissions.

As part of ARB's technical feasibility analysis of its proposed regulation to reduce GHG emissions, consistent with achieving a 33 percent RES, staff evaluated the GHG benefits from renewable energy technologies that may be used to satisfy the RES. This white paper discusses the renewable energy technology evaluated, the methodology used to quantify GHG benefits, presents preliminary results, and discusses future activities to refine these GHG benefits.

Renewable Energy Technologies

The staff evaluated energy technologies that are currently eligible for the RPS. Attachment 1 lists the eligible renewable energy technologies for the RPS program. In addition, staff is also evaluating other renewable energy technologies not currently eligible under the RPS. These technologies include: non-commercial solar, wind, and geothermal projects (i.e., residential level projects), combined heat and power (CHP), and run-of-river hydroelectric. The analysis does not signify that ARB staff are proposing to include these technologies.

Methodology

The GHG benefit analysis is based upon the "net" GHG emissions from the renewable energy technology, GHG emissions from the operation of the energy technology, and the GHG emissions associated with the incremental displacement of fossil fuel generation from the grid by renewable energy. Because this review considers the benefit provided by displacing one MW-hr of power from the grid with renewable energy, a capacity factor is not included in determining the GHG benefit for each renewable technology.

The net GHG emissions is the difference between the GHG emissions from using the renewable resource in an energy technology, such as an internal combustion engine (engine) generator, and GHG emissions from the typical use or disposal of the renewable resource. Some technologies do not emit GHG; therefore, the net GHG emissions for the technology are zero. This would apply to wind, solar, small hydroelectric, and ocean technologies. In the case where biomass or biogas is combusted directly (that is, the biomass is not transformed to a diesel or biogas) to generate electricity, staff assumed the GHG emissions would be the same if the biomass is allowed to decay in its natural environment or if the biomass is combusted in an energy device; consequently, the net GHG emissions are zero. In the case where biomass is converted to a fuel, for example, converting biomass to biodiesel, the energy associated with converting the biomass to biodiesel will be included in the GHG benefit determination. Finally, some technologies will emit GHG on a net basis—these include engines used in landfill and digester gas applications (comparing the case of GHG emissions from a flare to GHG emissions from the engine), geothermal power plants (comparing the case of no project versus a geothermal power plant), and waste-to-energy applications (comparing the case of waste used in the waste-to-energy plant to landfilling the waste).

The major benefit from using renewable power is the displacement of power produced by burning carbon-based fuels that would otherwise be used to meet the demand on the utility grid. The power being displaced is incremental power provided by generators to address load changes (“marginal power”), which is typically provided by natural gas power plants. With the integration of 33 percent renewable energy into the grid in 2020, the incremental power being displaced by renewable energy in 2020 is likely different than the incremental power that would be displaced by renewable energy today. That is, by 2020, the fossil fuel power plant fleet will differ from today’s fleet in that older and less efficient power plants, mainly utility boilers, will be retired and new more efficient gas turbine combined cycle power plants will be added to the fleet. Consequently, the GHG emissions associated with the incremental power generation will likely be lower as a result of integrating this amount of renewable energy. Staff will work with the staff of the CEC, Public Utilities Commission (PUC), and the California Independent System Operator (CAISO) to determine the GHG emissions associated with the incremental generation when 33 percent renewable generation has been added to the grid. For the purposes of this analysis, as shown in Attachment 2, GHG Benefit Determination for Renewable Sources, staff is using 1,100 lbs CO_2 equivalent per MWh as an estimate of the GHG emissions from the incremental power generation that is displaced as more qualifying renewable generation is placed in service from the grid. This value was developed by the CEC and is intended to be a GHG performance standard for new power plants that would be expected to come on-line if the RPS were not increased.

The related activities included with each GHG activity that staff evaluated are the GHG emissions from trucks used to transport material and the operation and maintenance activities at eligible renewable technologies. Staff evaluated the GHG emissions from trucks used in transportation and on-site activities for the different types of solar plants, the biomass combustion, and the biodiesel renewable energy technologies. Staff determined that, except for the biomass combustion technology, the GHG emissions related to transportation and operation and maintenance are minor. For the biomass combustion technology, the GHG emissions from transportation will be subtracted from the benefit determined for the technology. A discussion regarding quantifying the transportation GHG emissions for biomass combustion is given below.

Results and Discussion

Attachment 2, GHG Benefit Determination for Renewable Sources, provides a preliminary assessment of the GHG benefits for the renewable energy technologies currently eligible for the RPS. Overall, except for the case of combusting landfill or digester gas in an engine, the GHG benefit estimated for the renewable technologies are similar. As discussed below, the case of using landfill or digester gas in an engine due to increased methane emissions may result in lower overall displacement of GHG emissions than other renewable technologies reviewed in this paper. Staff will continue to evaluate the GHG benefits from this category. A detailed discussion of Attachment 2 is given below.

Staff evaluated the GHG benefits for wind and several types of solar energy plants. The GHG benefit is the difference between the GHG emissions avoided from the grid (that is, the fossil fuel power generation feeding into the grid). There are no GHG emissions from the technology itself. While wind and solar energy plants are intermittent sources which need occasional backup power from fossil fuel generation on the grid to make up periods of generation shortfall, staff did not include the backup power as part of the determination of the GHG benefits from wind and solar energy power. Such GHG emissions will be a function of time and location, as well as evolving technology (such as the penetration of large-scale storage and demand response). More information on the nature of such emissions will be forthcoming in CAISO operational studies and other analyses. Should these studies show that additional backup power for intermittent technologies is necessary, over and above what is typically used by CAISO to backup the grid, staff will include the GHG emissions associated with the additional backup power in determining the GHG benefits.

The GHG benefits for biomass combustion are based on the difference between the GHG emissions avoided from the grid and the GHG emissions from transporting biomass. As discussed above, the net GHG emissions from biomass combustion is assumed to be zero. This assumption considers the GHG emissions from biomass when it is left in the field to decay or is open burned would emit the same amount of GHG if that biomass is combusted in an energy plant. GHG emissions for transportation are based upon the operation data from the late 1990's for six California biomass-to-energy plants. The data includes the amount of biomass used by each plant and the GWh produced by each plant. Using this information and assuming each truck would carry 20 tons of biomass per trip and the truck would travel 80 miles roundtrip, staff estimated transportation GHG emissions as 70 lbs CO_2 equivalent per MWh.

The GHG benefits estimated for landfill and digester gas-to-energy is based upon the landfill gas control requirements in California. In California, the ARB recently approved a regulation that requires smaller uncontrolled landfills to install landfill gas collection systems and combust the collected gas in order to destroy methane emissions. Consequently, the base case for landfill projects in California is the use of a flare. To generate renewable power from landfill and digester gas, engines and turbines are used in place of a flare. As part of the development of the landfill regulation, ARB staff determined that lean-burn engines used to combust landfill gas have destruction efficiencies for methane of 87 to 95 percent—below the 99 percent destruction efficiency for a flare. The other energy technologies that can be used, such as a turbine and rich-burn engine, have similar destruction efficiencies as a flare. With the lower destruction efficiency for engines, and considering that methane is 21 times more potent as a GHG than CO_2, a comparison of the flare case versus the engine, would result in a net GHG increase of nearly 700 lbs CO_2 equivalent per MWh. Consequently, combusting landfill gas in a lean-burn IC engine is the only technology that has GHG benefits that are significantly lower than the other technologies being reviewed. Staff will continue to review the GHG benefits for potential landfill and digester energy, particularly the benefits of projects located in other states that are connected to the WECC and may provide power to California.

The GHG benefit of converting biomass into a biodiesel and subsequently using the biodiesel in an energy device is the GHG emissions avoided from the grid minus the GHG emissions associated with converting biomass to biodiesel. To estimate the energy needed to convert biomass into renewable diesel, staff evaluated the energy needed to use the Fischer-Tropsch (F-T) process to produce biodiesel. The F-T process is energy intensive, but in addition to producing biodiesel, electricity and naphtha are produced as co-benefits. The power system GHG emissions reported in Table 2 includes the GHG emissions emitted during the production of the biodiesel and subtracts the electricity co-benefit. Finally, because of the high cost for a F-T facility, it's unlikely that a F-T facility would be constructed to manufacture biodiesel from biomass.

Biogas injection refers to the injection of a renewable biogas, such as landfill gas, into a natural gas fuel line. This mixture of biogas and natural gas would subsequently be combusted in a natural gas power plant. The GHG benefit is proportional to the amount of biogas that is combusted instead of natural gas in the power plant.

For geothermal plants, the GHG benefit is the GHG emissions avoided from the grid minus the emissions from the plant (for this technology, the net GHG emissions is the GHG emissions from the plant minus the GHG emissions for the case where there is no geothermal plant). Geothermal plant CO_2 emissions are site specific and are emitted as part of the process of utilizing the thermal energy (CO_2 is in the geothermal stream and CO_2 is emitted when the geothermal stream is processed by the plant). The low CO_2 factor and high CO_2 factor represent estimates for various technologies.

For small hydropower and ocean technologies, since the technology itself has no GHG emissions, the GHG benefit is simply the GHG emissions avoided from the grid. Similarly, the fuel cell is assumed to be using a renewable fuel, such as digester gas from a waste treatment facility; therefore the GHG benefit is the GHG emissions avoided from the grid.

Finally, for MSW applications, the GHG benefits are the GHG emissions avoided from the grid minus the net emissions. In this case, the net emissions are based on the GHG emissions from the MSW plant less the GHG emissions from the landfill (no MSW plant case). The GHG emissions from landfills vary significantly, depending upon the type of waste in the landfill, the moisture the landfill receives, and other factors. Staff is evaluating information to determine the GHG emissions from a typical landfill in California.

Summary

Staff reviewed the GHG benefits for all renewable energy technologies that are eligible for the RPS. Based on preliminary results, most of the renewable energy technologies have similar GHG benefits. Staff will continue to review the analysis in the following areas: GHG benefits from landfill or digester gas used in engines and MSW combustion / conversion projects; evaluate whether other renewable energy technologies should have eligibility for the RES; and estimating the GHG emissions for incremental power generation from the grid in 2020.

Attachment 1
Renewable Technologies Eligible
For the Renewable Portfolio Standards (RPS)[1]

Type of Renewable Generation	Description
Biogas Injection into Natural Gas Pipeline	Renewable fuel injected into pipeline to be used in a power plant. The biogas injected into the natural gas pipeline must be delivered to California for use in an RPS-eligible facility.
Biomass Combustion	Combustion of biomass in a biomass boiler or fluidized bed to generate electricity.
Conduit Hydroelectric	A hydroelectric facility that uses only the potential of an existing pipe, ditch, flume, siphon, tunnel, canal, or other mandated conduit that is operated to distribute water for a beneficial use. A conduit hydroelectric facility may be considered a separate project even though the facility itself is part of a large hydroelectric facility.
Converting Biomass To Biodiesel	Biomass is converted by a chemical process to biodiesel and the biodiesel is used to power an engine or turbine to generate electricity.
Geothermal Energy	Uses the earth's heat to generate steam to be used in a power plant to generate electricity. The four types of geothermal power plants are: Flash, dry stream, binary, and flash/binary combined power plants.
Fuel Cell	Converts the energy of a renewable fuel directly to electricity and heat, without combustion. Only the electricity generated by the fuel cell is RPS eligible.

[1] This table provides a general description of most of the renewable energy technologies eligible for the RPS program. Other requirements may be applicable—see CEC guidebook: Renewables Portfolio Standard Eligibility.

Landfill / Digester Gas to Energy	Use landfill gas or digester gas as fuel in an engine or turbine to generate electricity
MSW Combustion	Converts municipal solid waste into thermal energy by using combustion. Typically, this process uses an incinerator to combust the MSW. The heat given off by the process is then used to heat a boiler to generate electricity.
MSW Conversion	Converts municipal solid waste into fuel gases or liquid fuels through non-combustion thermal process that does not use air or oxygen in the conversion process, except ambient air to maintain temperature control and produces no discharges of air contaminants or emissions, including GHG emissions.[2] This clean burning gas is then burned to generate electricity.
Ocean Technologies	Includes ocean thermal, ocean wave, and tidal current.
Ocean Thermal	This technology uses the thermal potential of different depths of the ocean to generate electricity.
Ocean Wave	Converts the energy in ocean wave motion into electric energy. Technologies include, but are not limited to: point absorbers, oscillating water column, overtopping terminator, and attenuator.
Photovoltaic	Converts solar radiation into electricity using a semiconductor.
Small Hydroelectric	Uses a turbine to convert the kinetic energy of flowing water into electrical energy. A small hydroelectric project is defined as providing 30 MW or less, except for eligible efficiency improvements that meet certain criteria.
Solar Thermal	Converts solar radiation into thermal energy. Technologies including, but not limited to

[2] See Health and Safety Code Section 42801.1 and Public Resources Code 25741(b)(3)

	solar trough , stirling engine, solar dish, and solar tower.
Tidal Current	Uses the potential energy difference caused by the change in tide levels to drive turbines to generate electricity.
Wind	Converts the kinetic energy of wind into electrical energy.